

Using hindcasts to improve depiction of the MJO in next-generation climate models

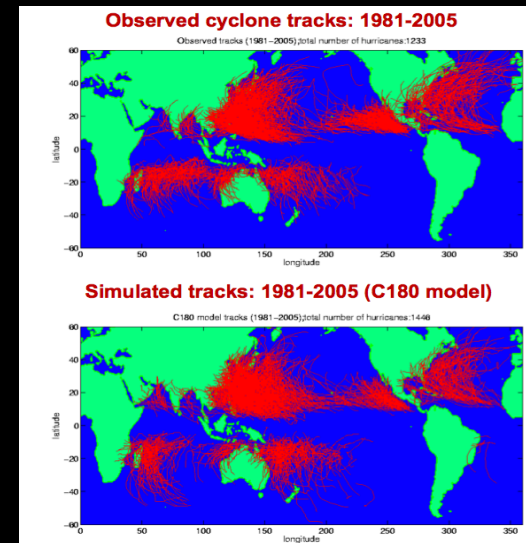
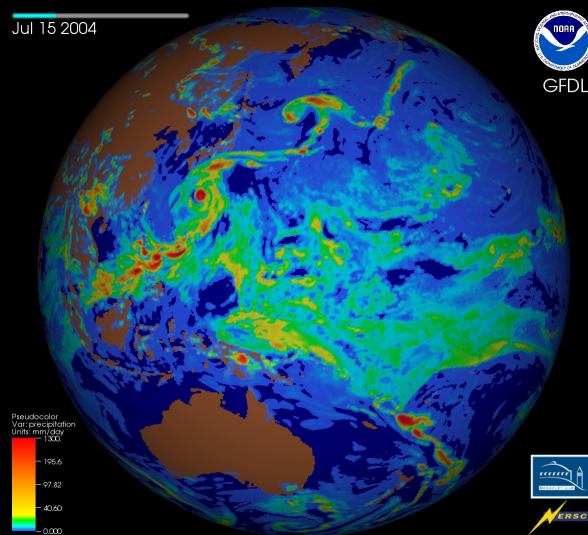
Stefan Tulich

CIRES, Univ. of Colorado and NOAA/ESRL Boulder, CO

Co-PIs: Julio Bacmeister¹, Bill Putman², Max Suarez², and Ming Zhao³

¹NCAR/CGD, ²NASA/GMAO, ³NOAA/GFDL

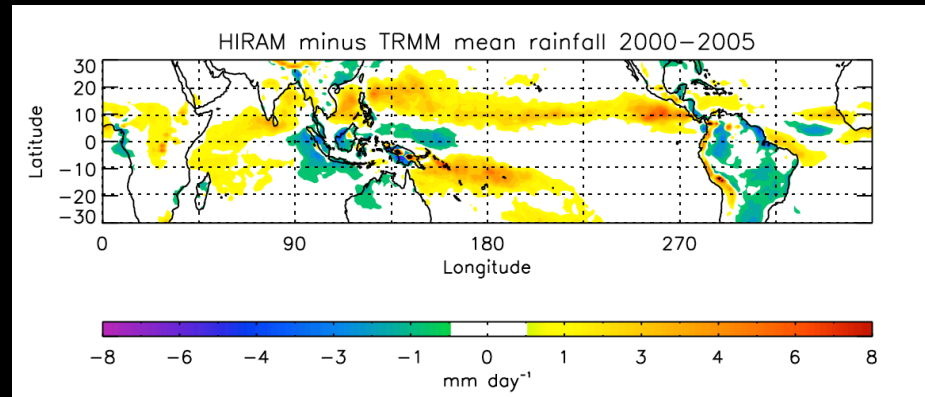
Global climate simulations with $\Delta x \sim 30$ km are now routine



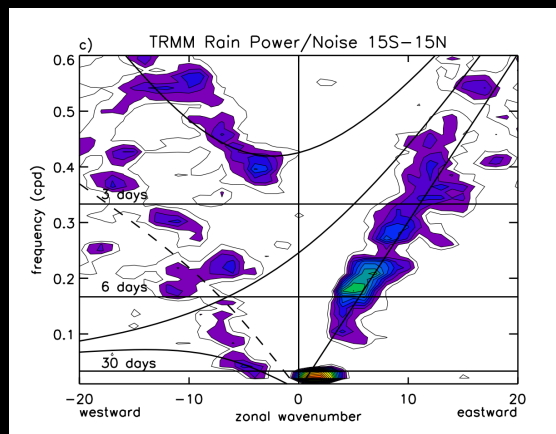
e.g., HIRAM (NOAA/GFDL)

However, significant biases and deficiencies still remain

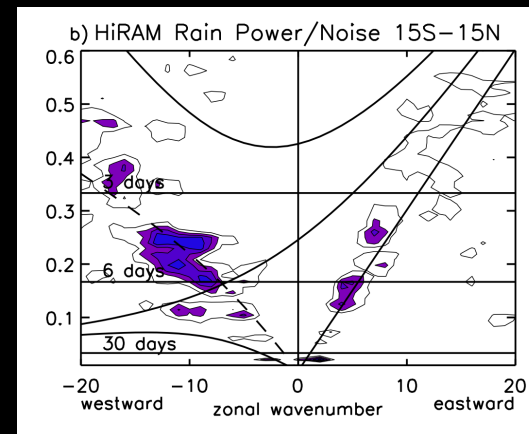
Mean rain bias



Obs. tropical rain spectrum



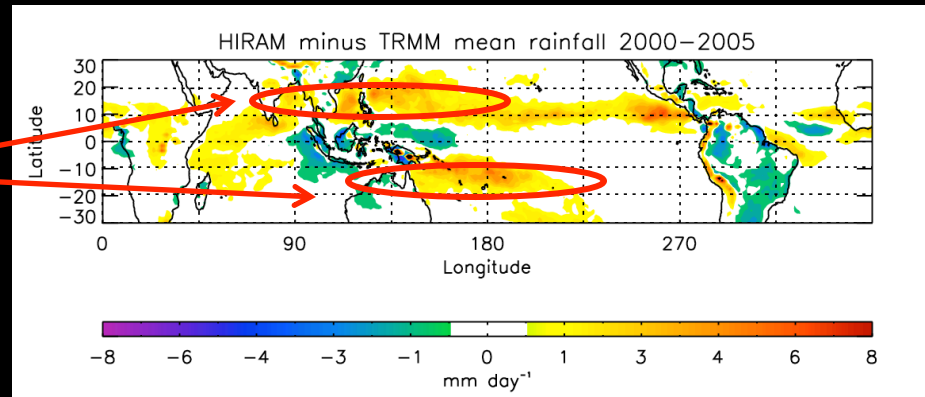
Model tropical rain spectrum



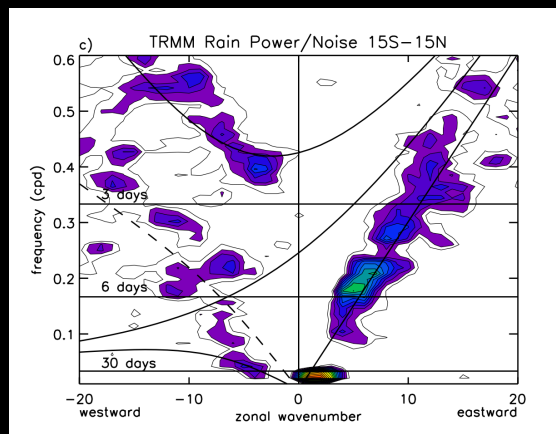
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Mean rain bias

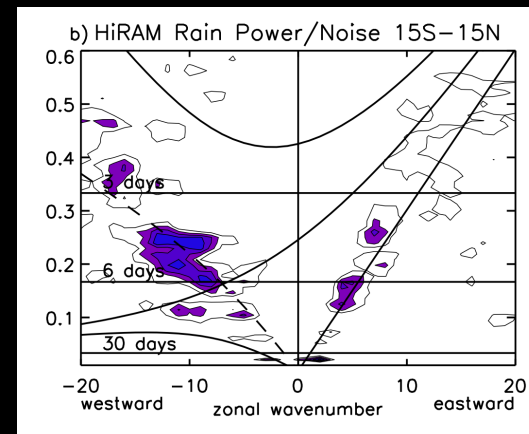
Too much off-eq. rain



Obs. tropical rain spectrum

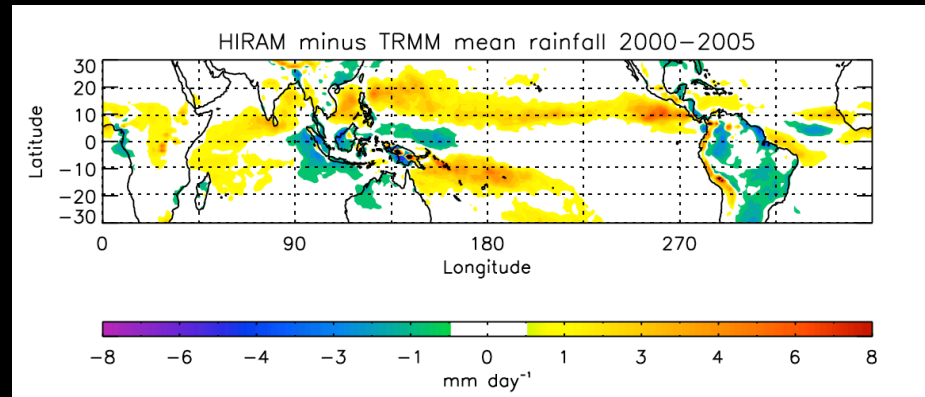


Model tropical rain spectrum

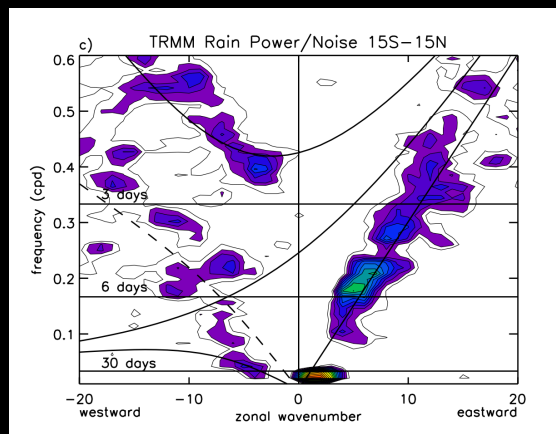


However, significant biases and deficiencies still remain

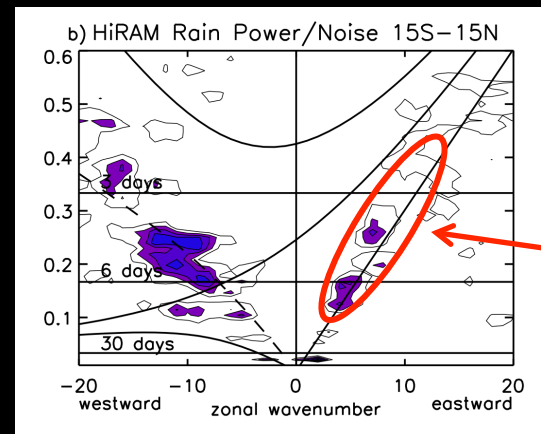
Mean rain bias



Obs. tropical rain spectrum



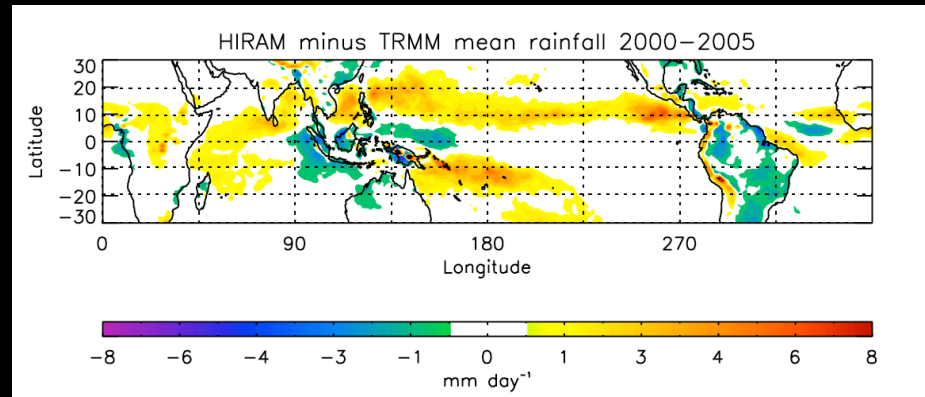
Model tropical rain spectrum



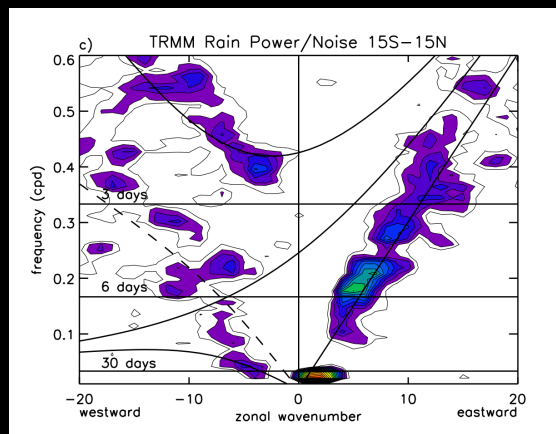
Kelvin waves
too weak

However, significant biases and deficiencies still remain

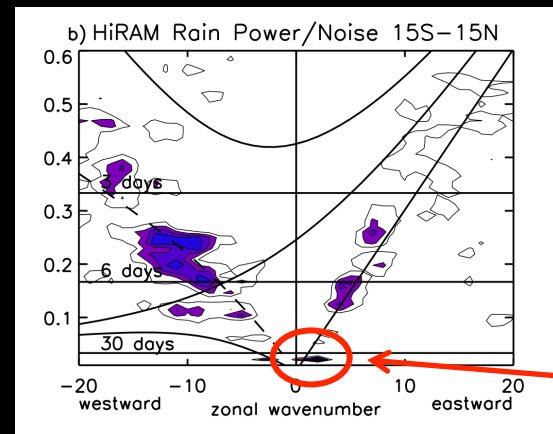
Mean rain bias



Obs. tropical rain spectrum

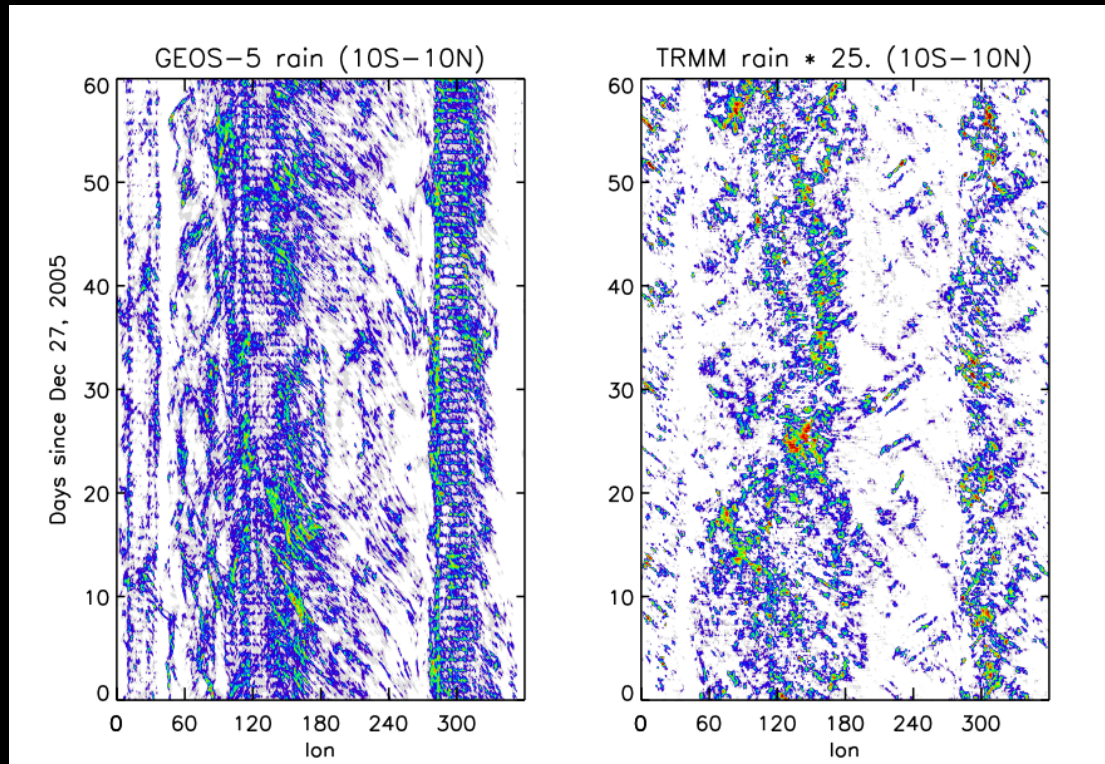


Model tropical rain spectrum



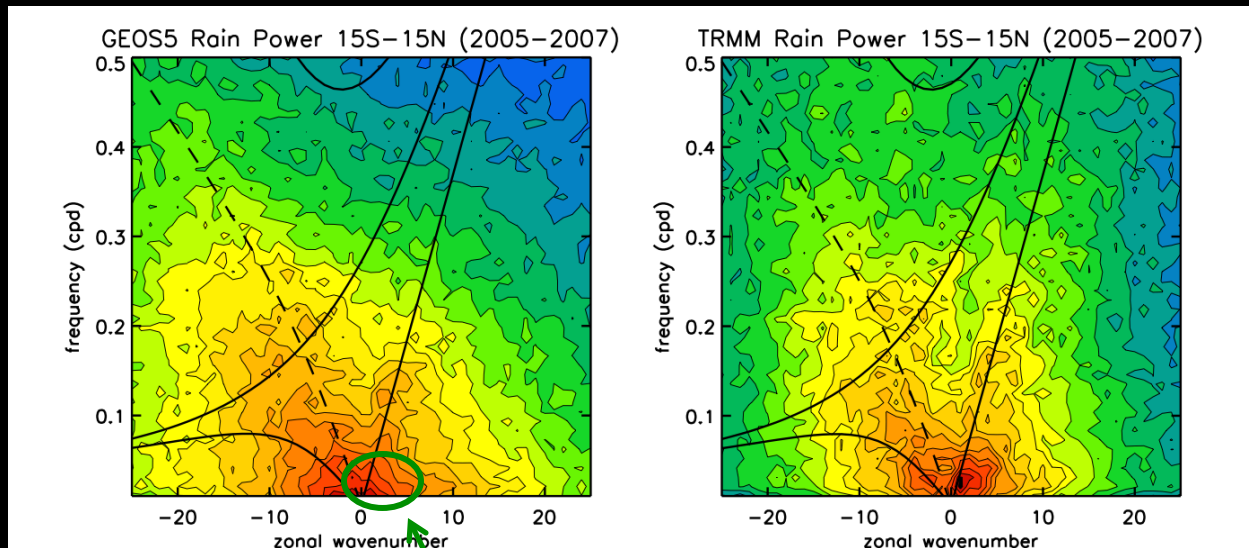
Virtually
no MJO

What happens if we go to even higher resolution?



NASA GEOS-5 at ~12 km grid spacing (2-yr run)

What happens if we go to even higher resolution?

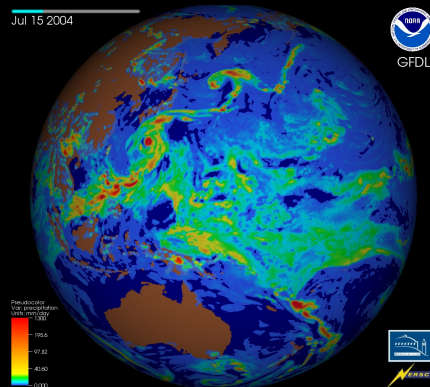


And still
no MJO!

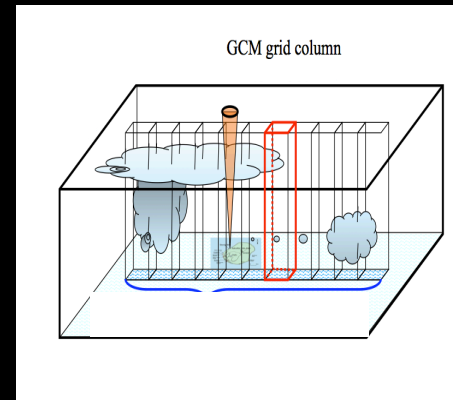
NASA GEOS-5 at ~12 km grid spacing (2-yr run)

Project strategy

- To understand and mitigate these deficiencies, use “high-resolution” global climate models and expanded NOAA computing resources (GAEA) to perform 30-day hindcasts of the MJO
- Two types of models:
 - 1) Traditional global model
 - 2) “Superparameterized” global model



Computing spent on resolving a continuous range of scales (40,000 – 25 km)

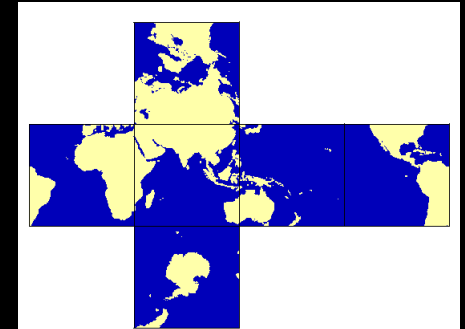
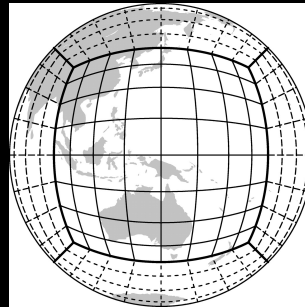


Computing spent mainly on resolving the convective scale [O(1 km)] at the expense of intermediate mesoscales

Models involved

- Traditional models:

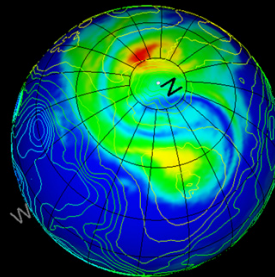
- 1) HIRAM (GFDL)
- 2) GEOS-5 (NASA)
- 3) CAM5 (NCAR)



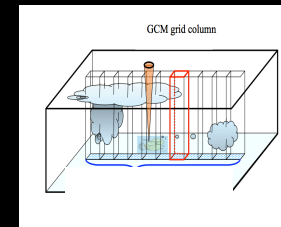
Finite-volume, cubed-sphere dynamical core

- SP model: WRF

3D Global WRF



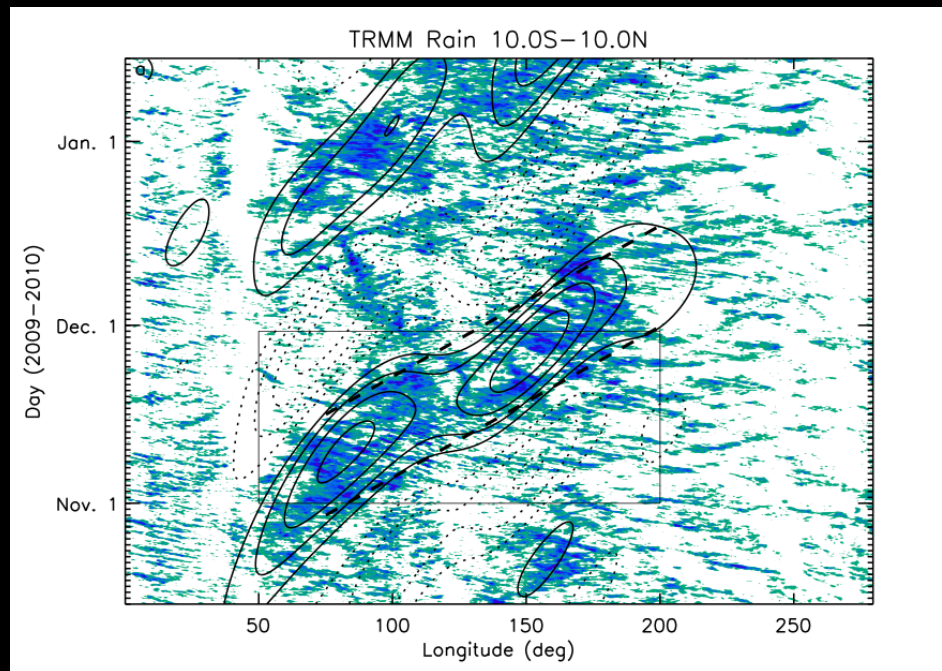
2D WRF



Finite-difference, lat-lon dynamical core with polar filtering

Specific MJO event

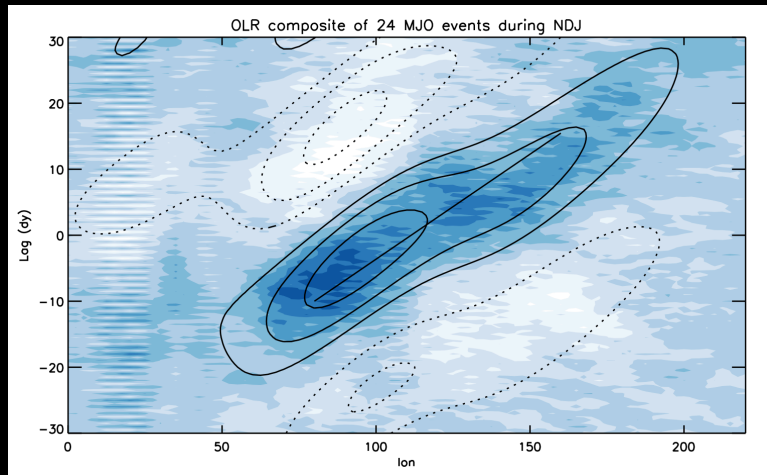
2009 YOTC Case E* (Nov-Dec)



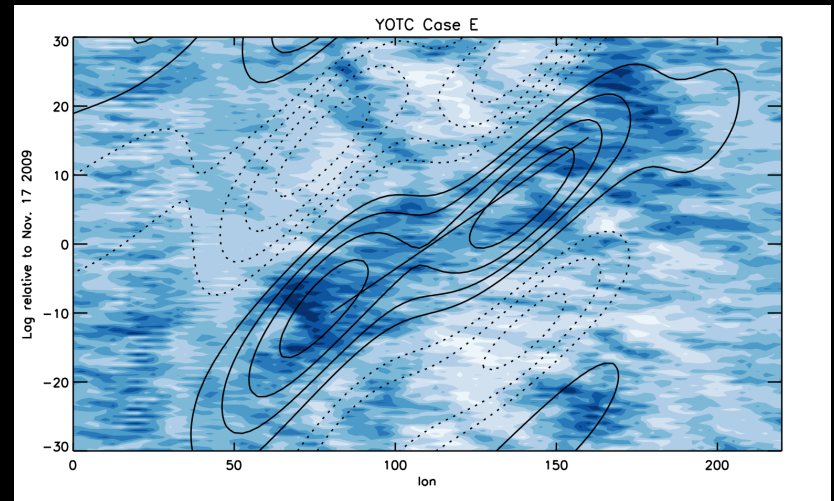
Note*: Also the focus of a global model hindcast intercomparison project of the WCRP-WRRP/Thorpe MJO Task Force

How representative is Case E?

OLR composite of 24 events



Case E

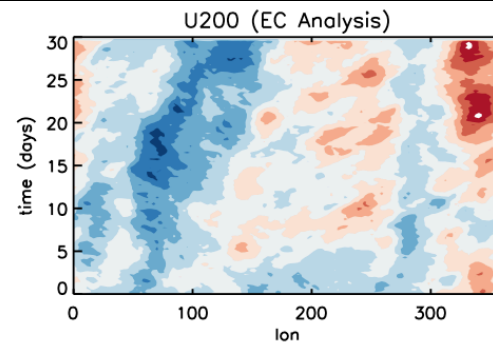
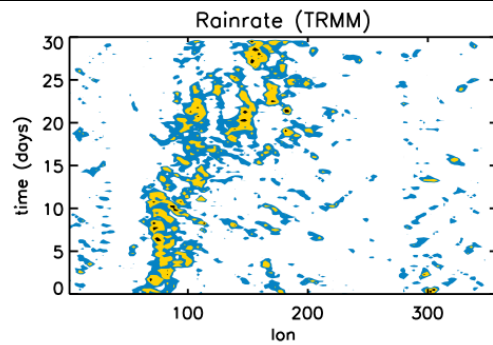


Hindcast setup

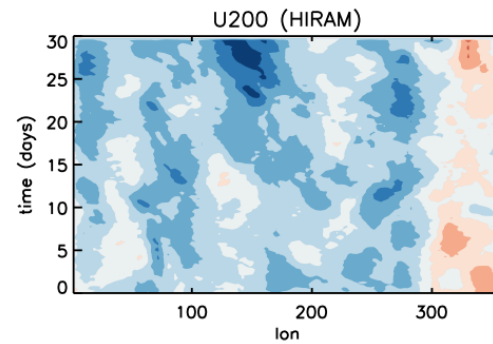
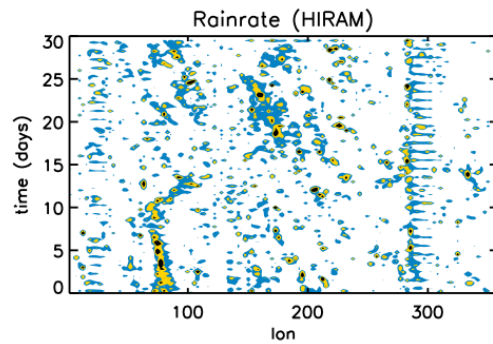
- Models are nudged to an analysis for a period of days to weeks prior to the start date
- Traditional models each have Δx of ~ 25 km
 - Convection handled partly through explicit dynamics (i.e., grid-scale updrafts) with diagnostic microphysics and partly by standard convection scheme; partitioning is model dependent
- SP-WRF has a global Δx of 2.8 deg and CRM Δx of 4 km (32 points)

Nov 1 hindcast results: HIRAM

Obs.

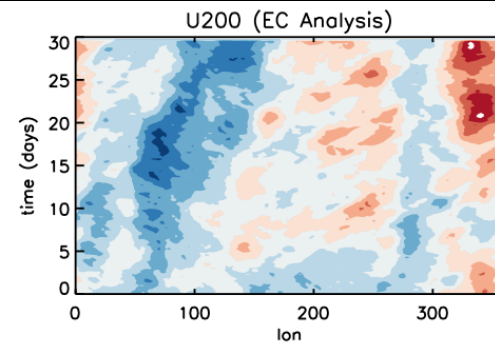
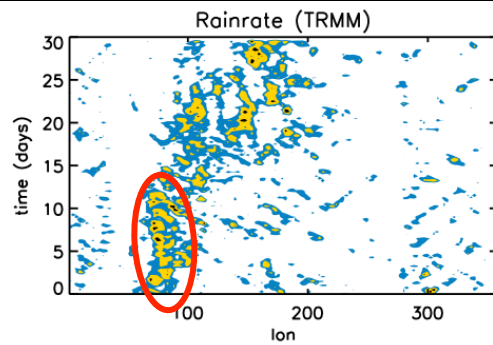


HIRAM

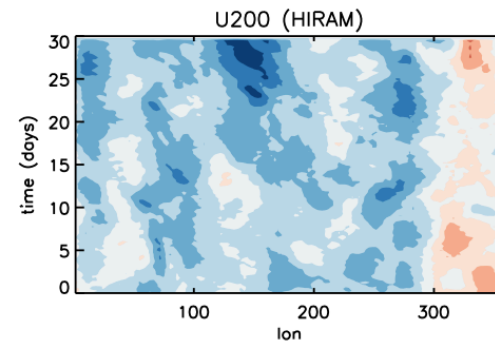
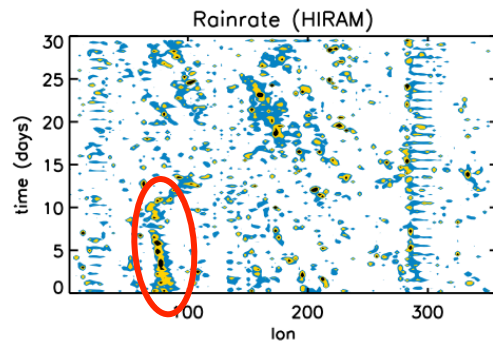


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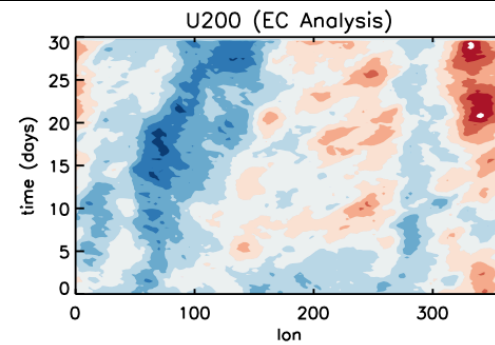
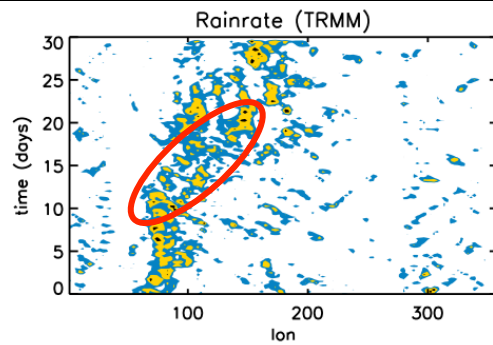


HIRAM

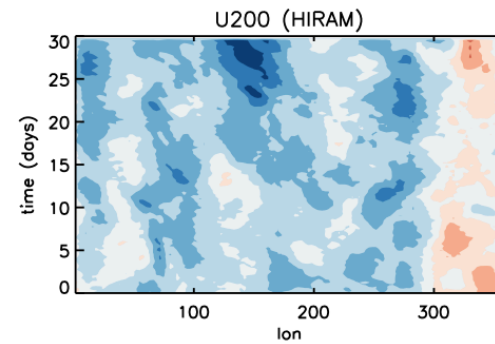
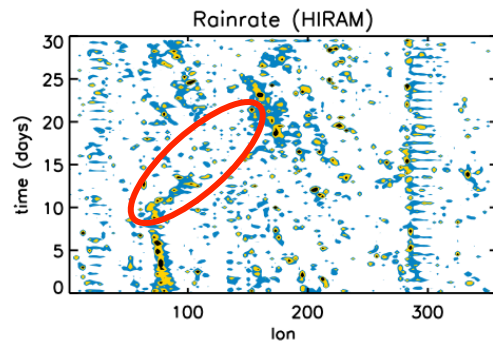


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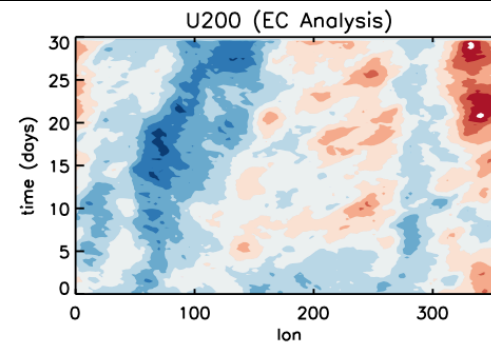
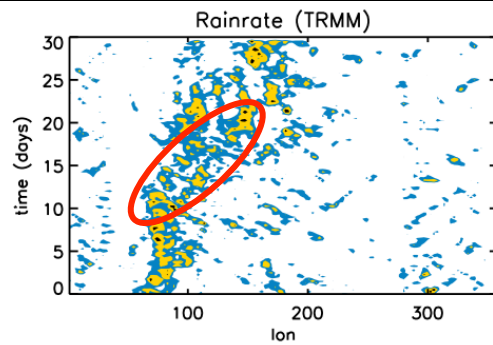


HIRAM

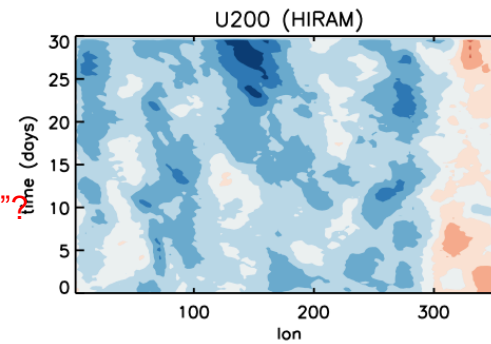
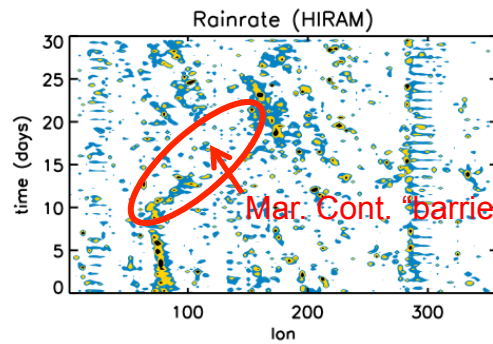


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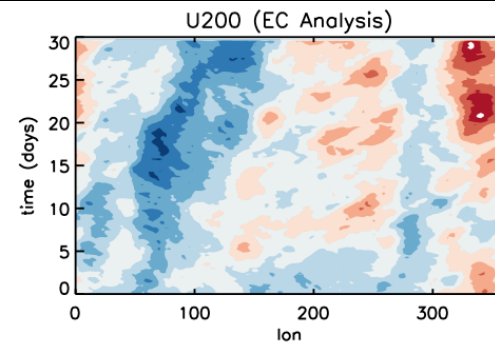
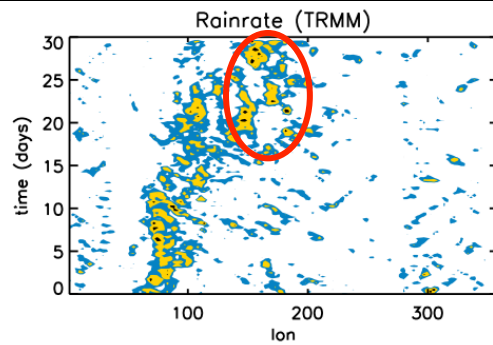


HIRAM

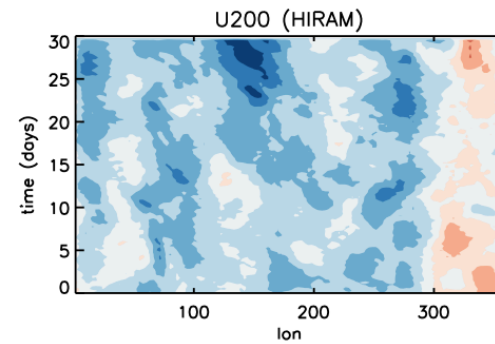
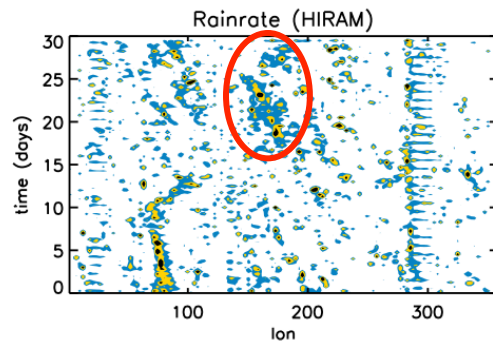


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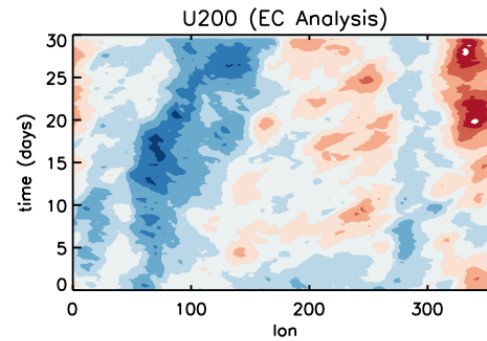
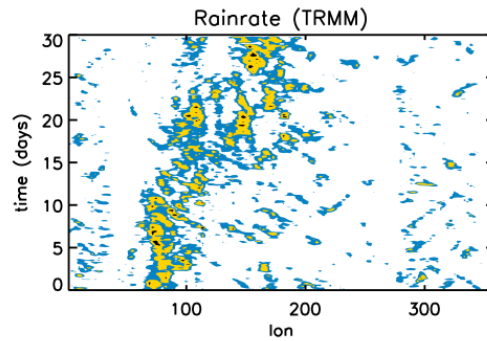


HIRAM

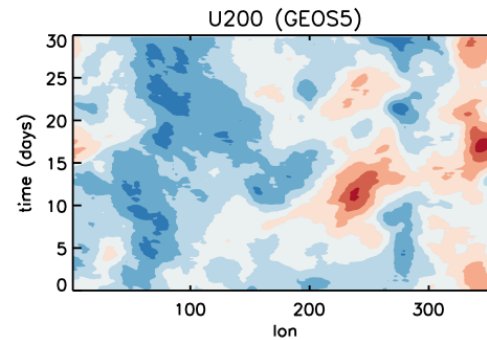
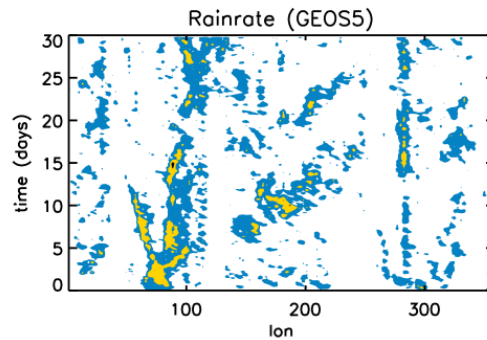


Nov 1 hindcast results: GEOS-5

Obs.

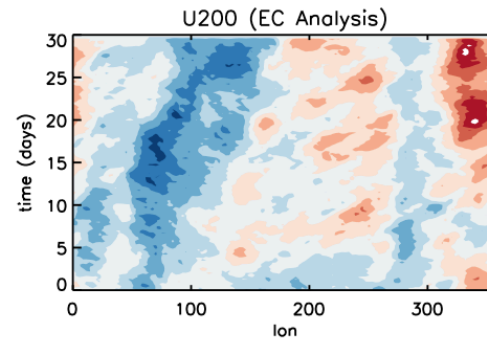
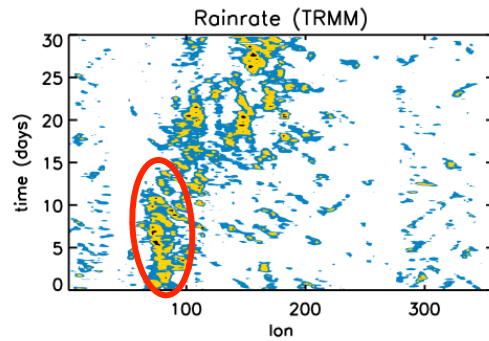


GEOS-5

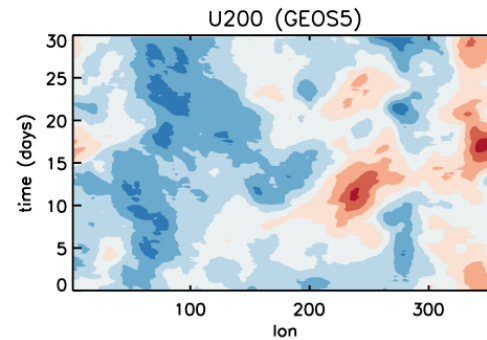
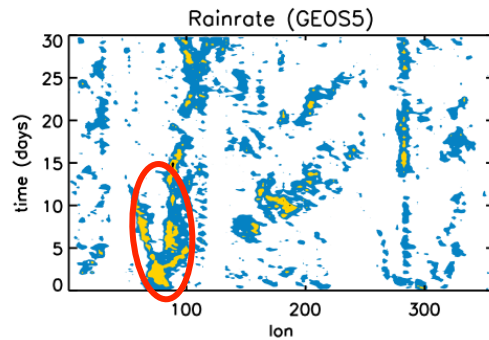


Nov 1 hindcast results: GEOS-5

Obs.

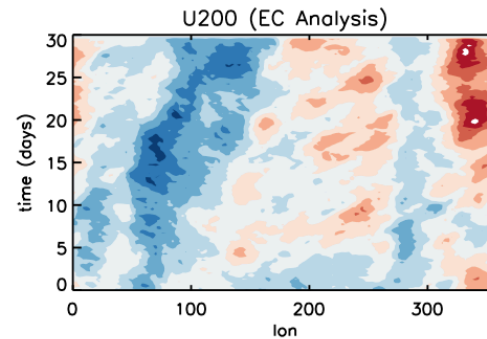
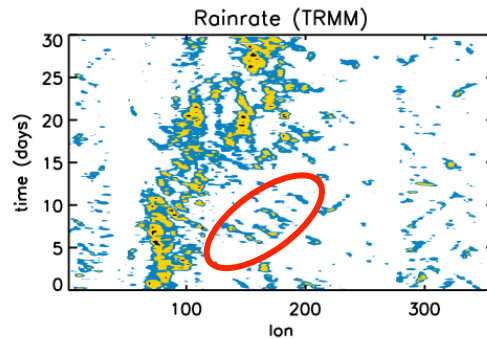


GEOS-5

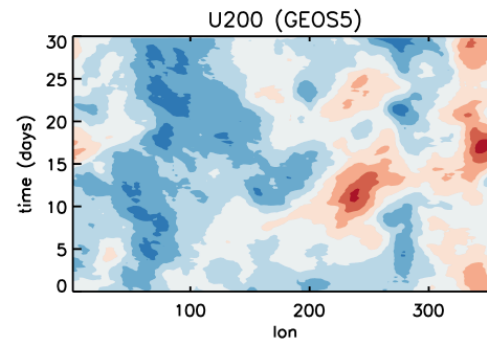
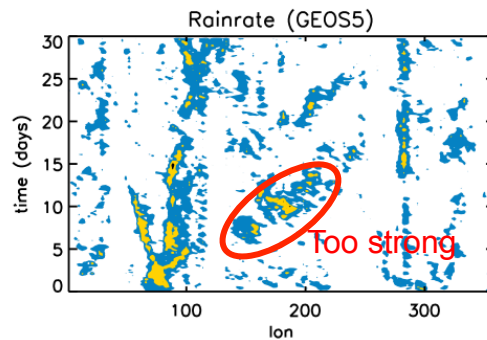


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Obs.

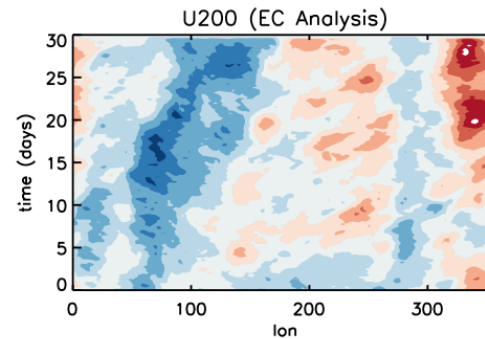
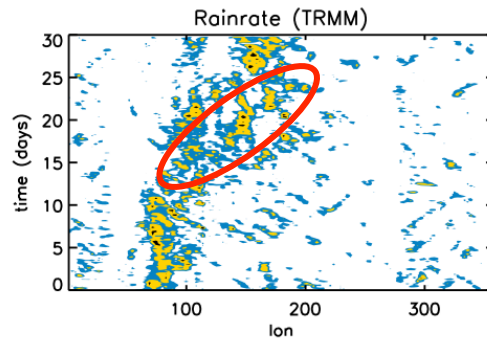


GEOS-5

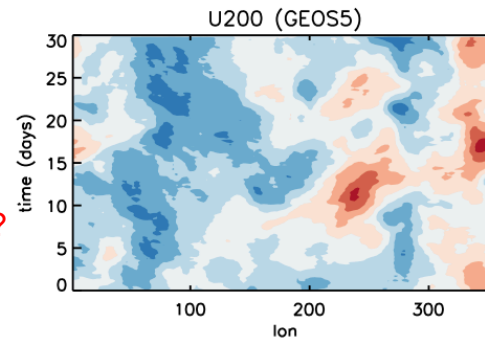
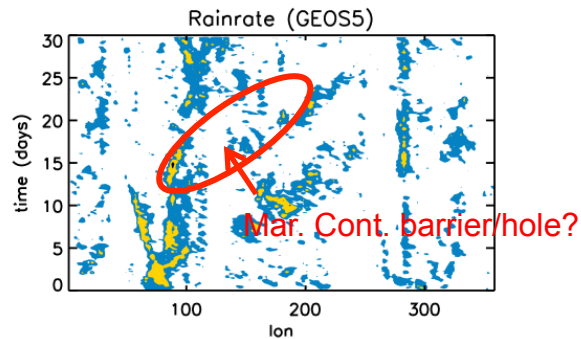


Nov 1 hindcast results: GEOS-5

Obs.

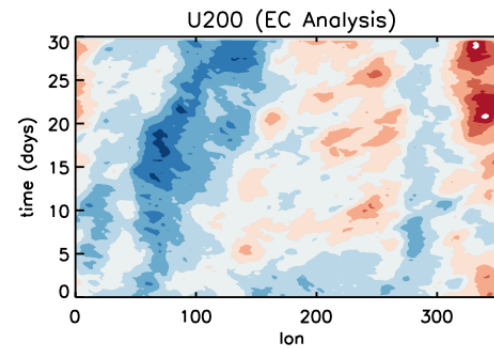
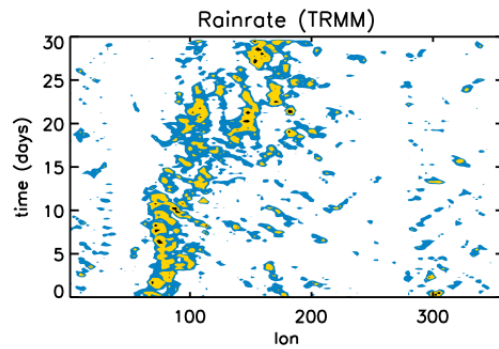


GEOS-5

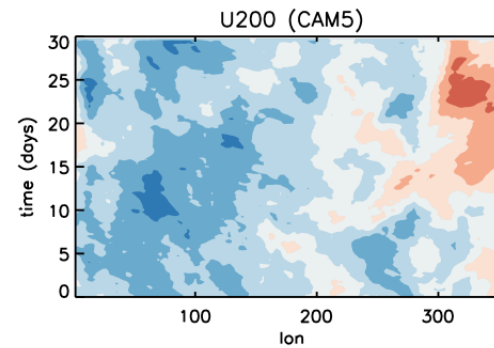
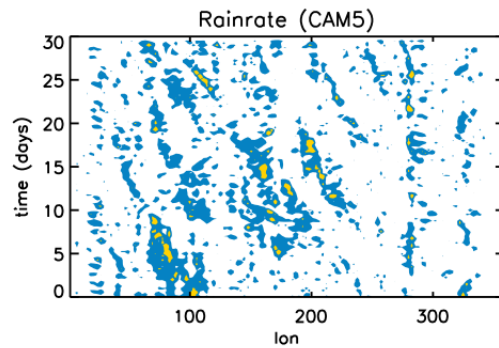


Nov 1 hindcast results: CAM-5

Obs.

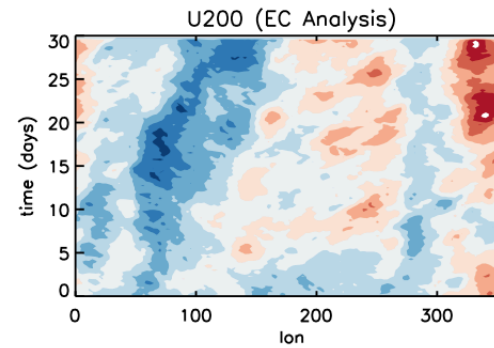
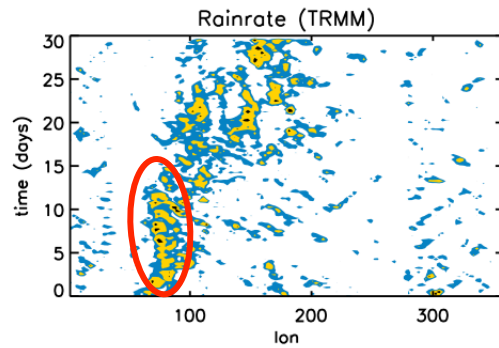


CAM-5

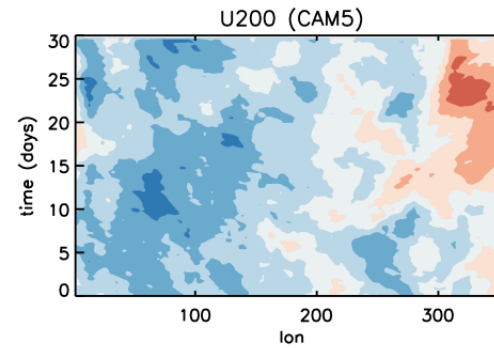
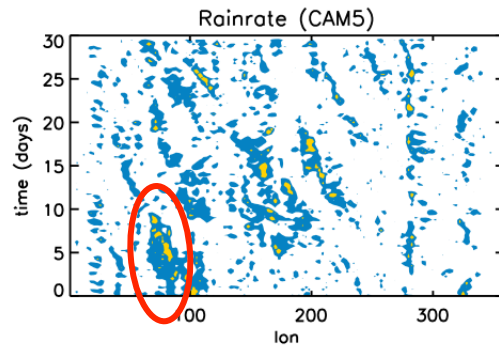


Nov 1 hindcast results: CAM-5

Obs.

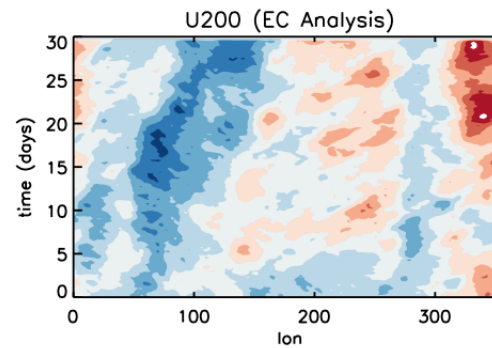
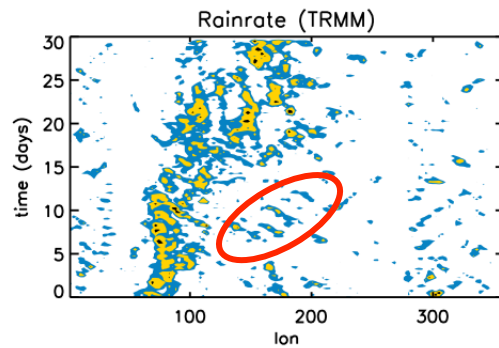


CAM-5

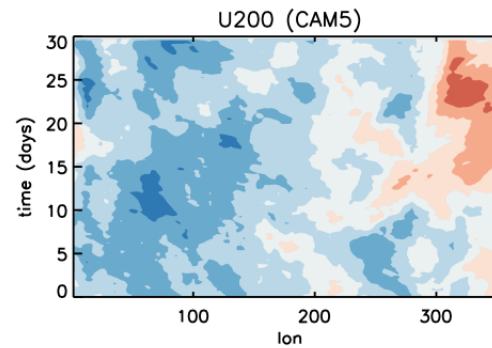
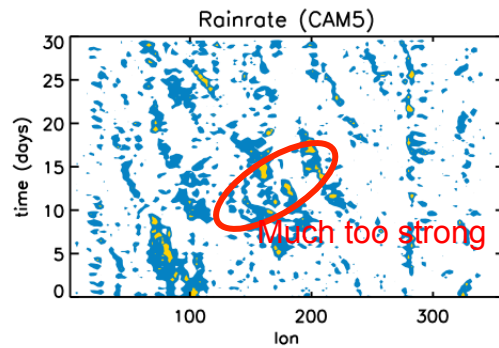


Nov 1 hindcast results: CAM-5

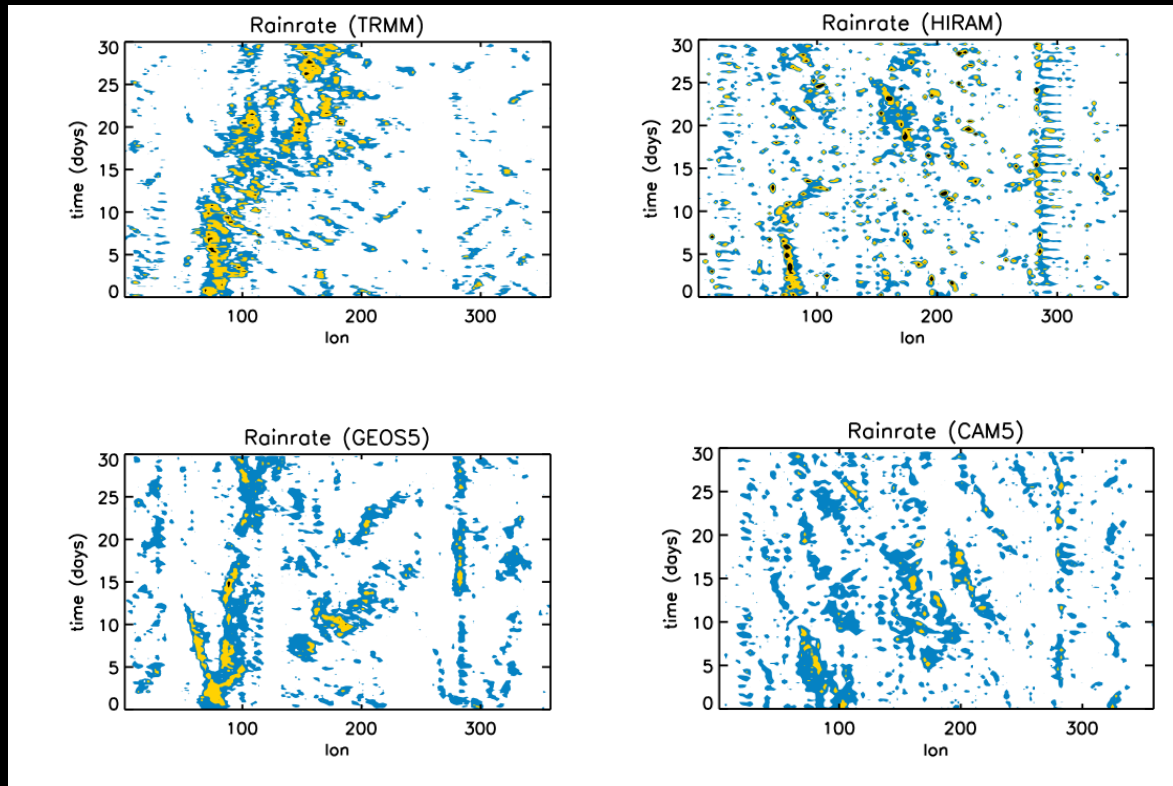
Obs.



CAM-5



Why is HIRAM's rain more “pointillistic” than GEOS-5/CAM-5?

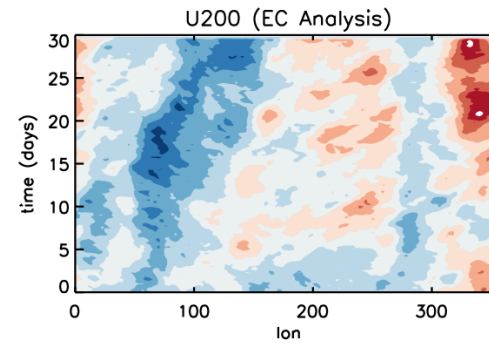
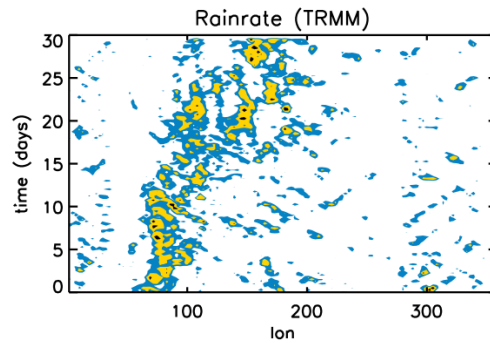


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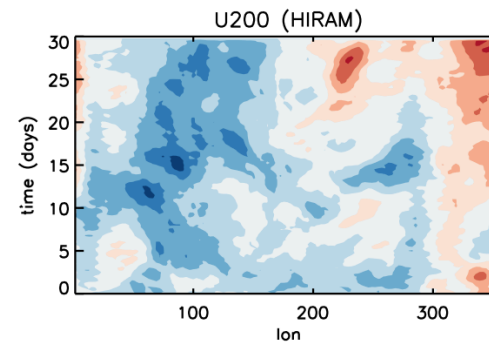
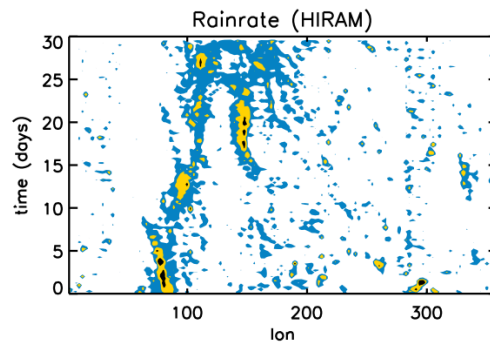
- Hypothesis: deep convection in HIRAM is handled too much by grid-scale updrafts vs. parameterized updrafts (a single, strongly-entraining bulk-plume model)
- Test: Add a second more weakly-entraining bulk plume

HIRAM 50-km (double plume)

Obs.



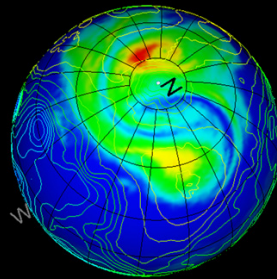
HIRAM



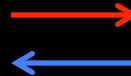
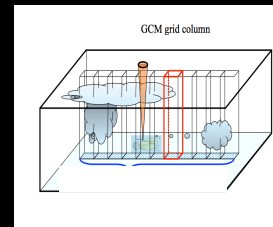
Turning to superparameterization for further guidance

Fundamental question: given explicit (4-km) treatment of moist processes in a small 2D domain, what aspects of the problem still remain?

3D Global WRF



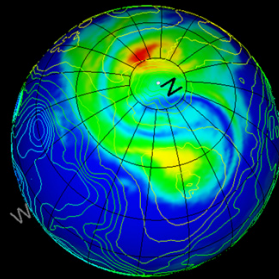
2D WRF



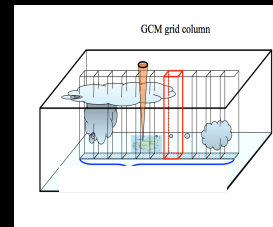
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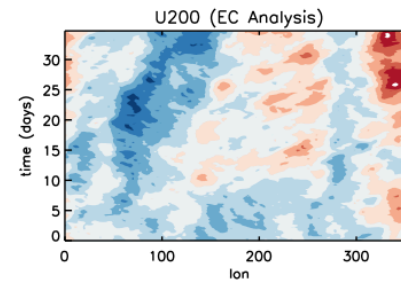
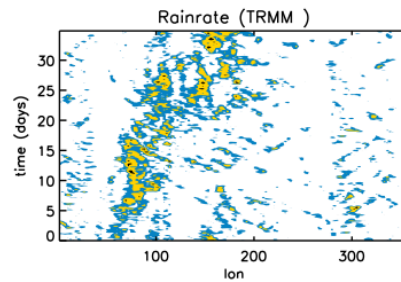
2D WRF



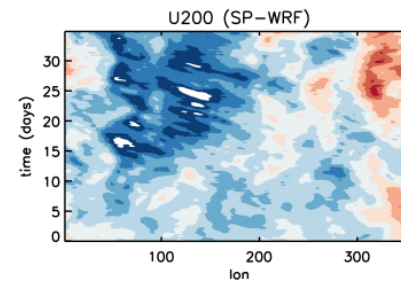
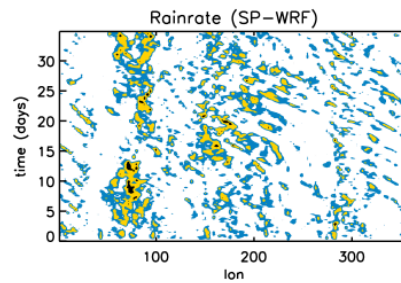
For example: how do results depend on the treatment of SGS vertical mixing in the CRM? What about horizontal resolution of the large-scale model?

Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

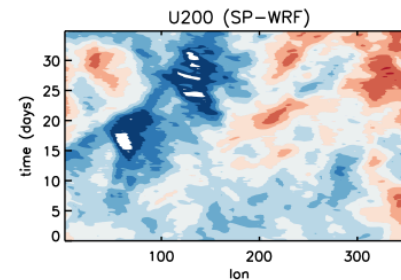
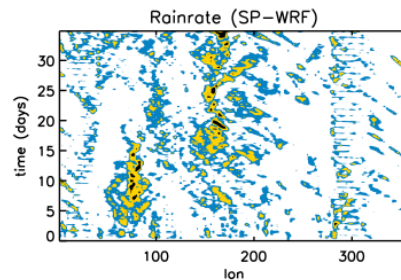
Obs.



MYNN2.5 PBL
(more diffusive)

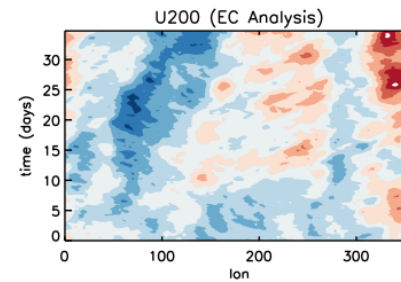
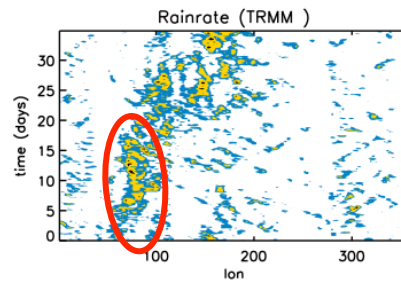


3D SMAGORINSKY
(less diffusive)

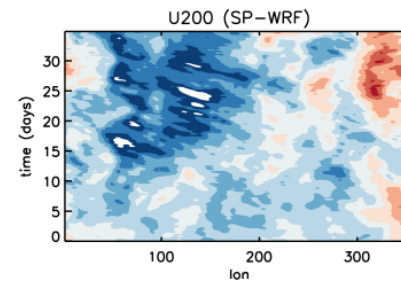
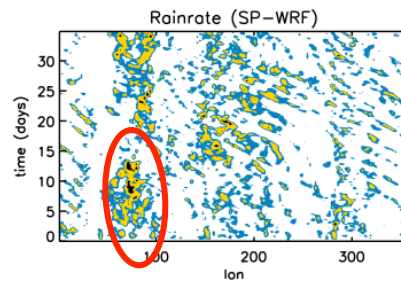


Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

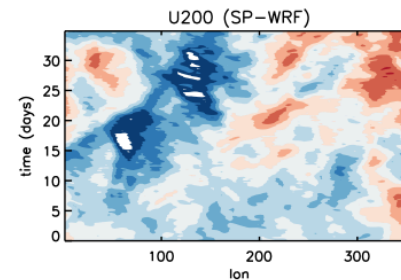
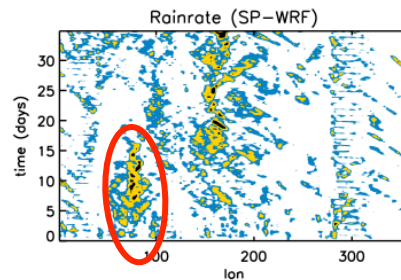
Obs.



MYNN2.5 PBL
(more diffusive)

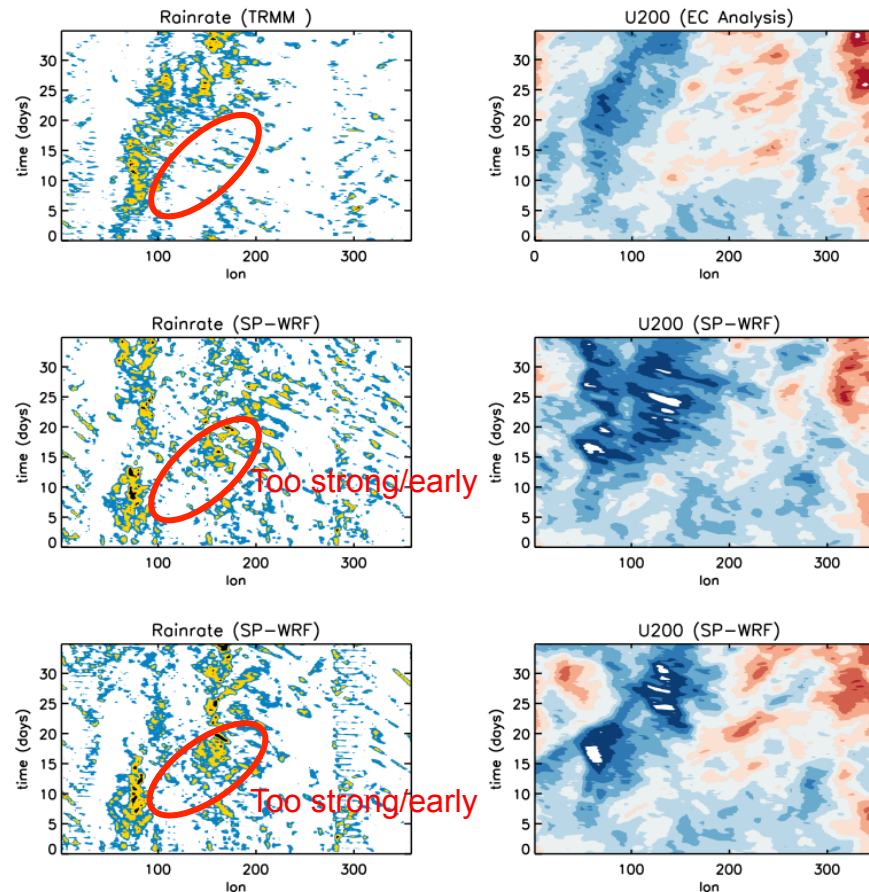


3D SMAGORINSKY
(less diffusive)



Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

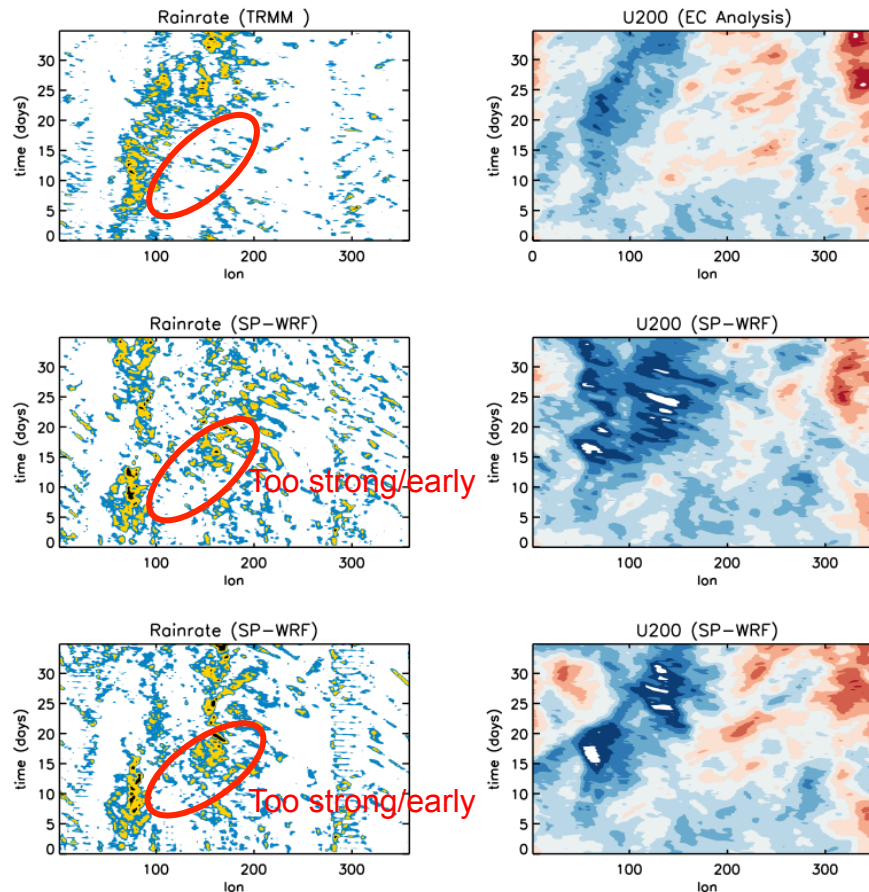


MYNN2.5 PBL
(more diffusive)

3D SMAGORINSKY
(less diffusive)

Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

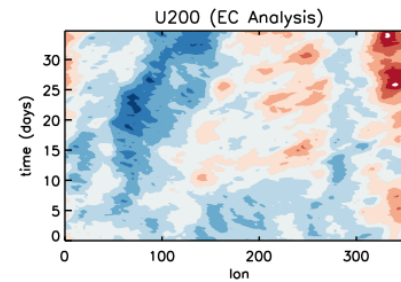
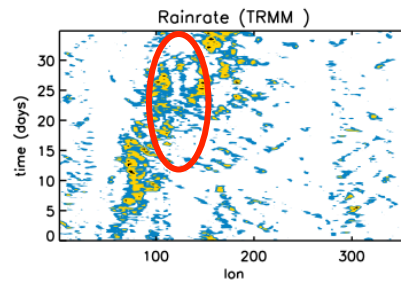


MYNN2.5 PBL
(more diffusive)

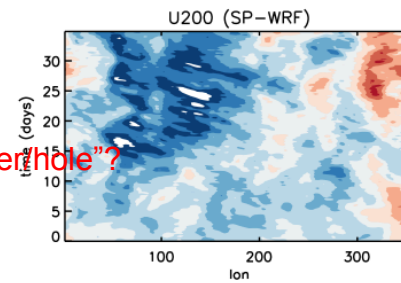
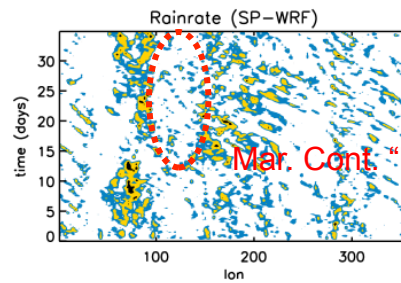
3D SMAGORINSKY
(less diffusive)

Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

Obs.

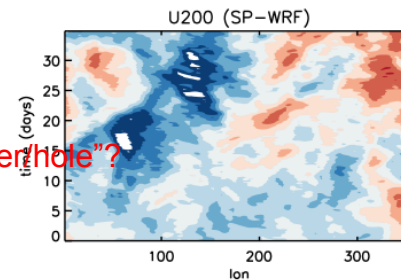
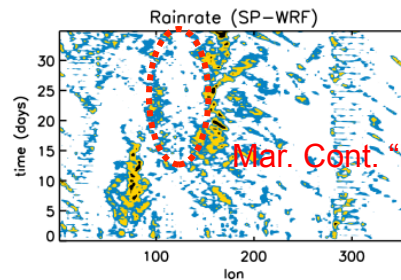


MYNN2.5 PBL
(more diffusive)



Mar. Cont. "barrierhole"?

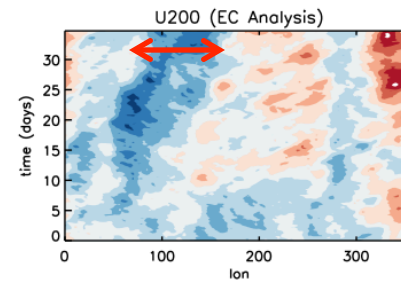
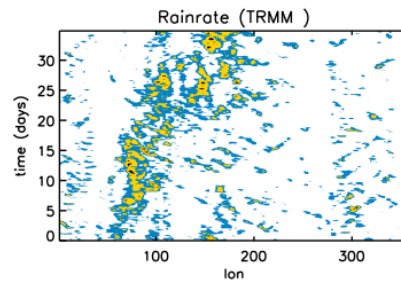
3D SMAGORINSKY
(less diffusive)



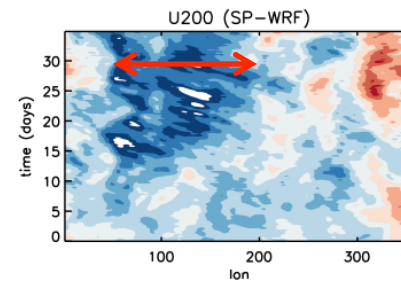
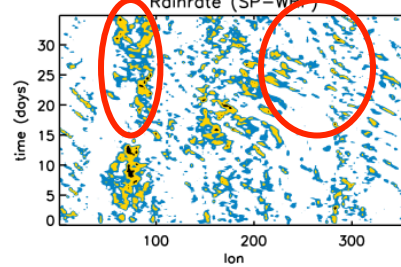
Mar. Cont. "barrierhole"?

Nov 1 hindcast: SP-WRF (sensitivity to SGS vertical mixing)

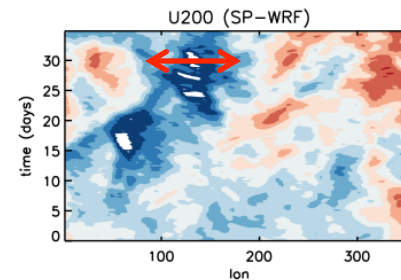
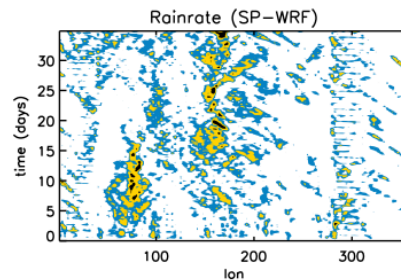
Obs.



Too active elsewhere

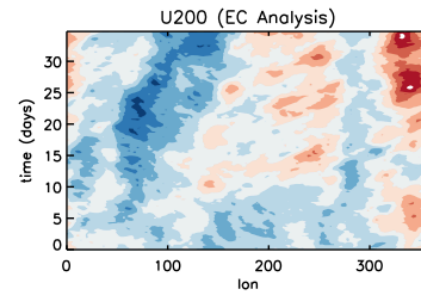
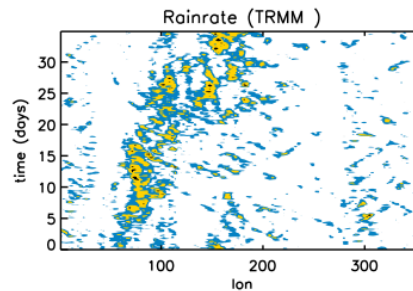


3D SMAGORINSKY
(less diffusive)

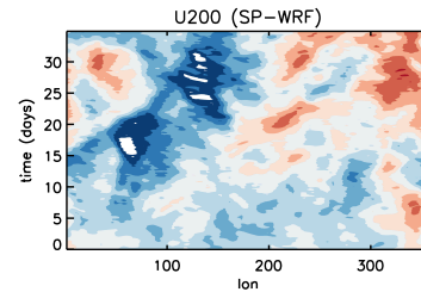
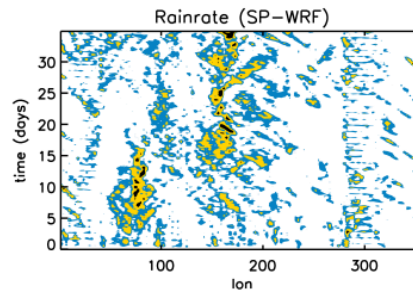


Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

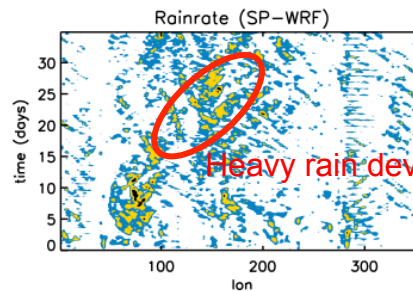
Obs.



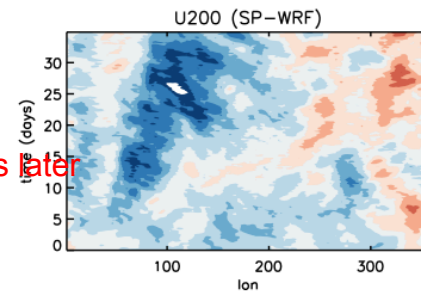
2.8deg (32x4km)



0.7deg (12x4km)
8 x more exp.

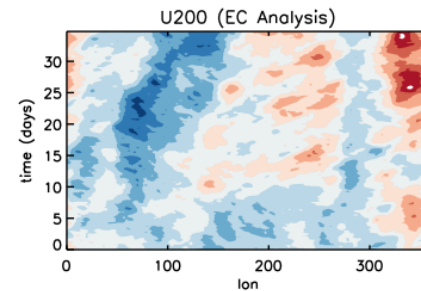
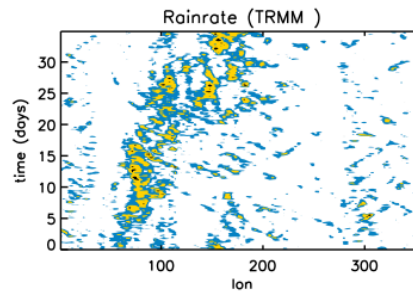


Heavy rain develops later

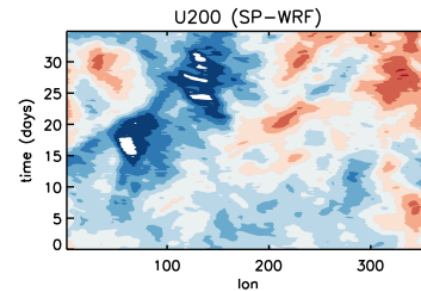
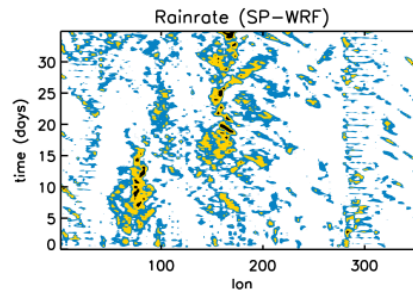


Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

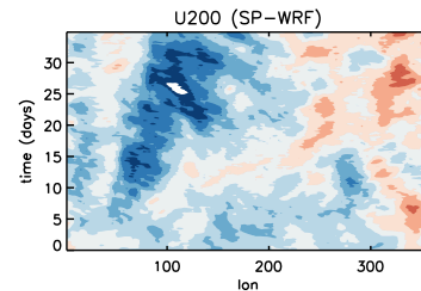
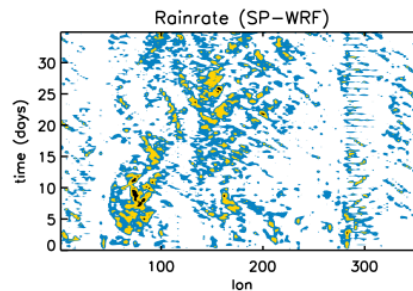
Obs.



2.8deg (32x4km)

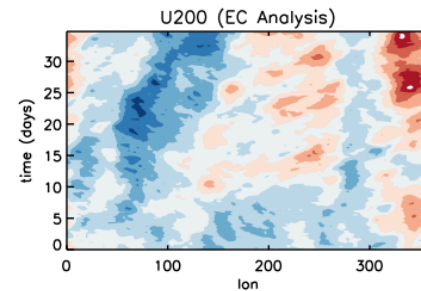
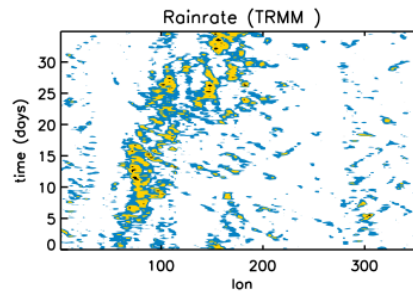


0.7deg (12x4km)
8 x more exp.

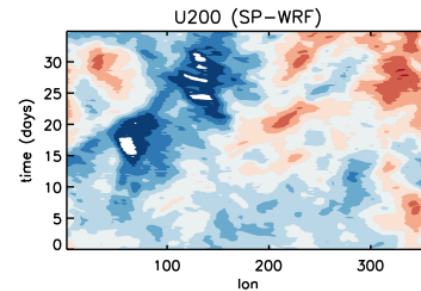
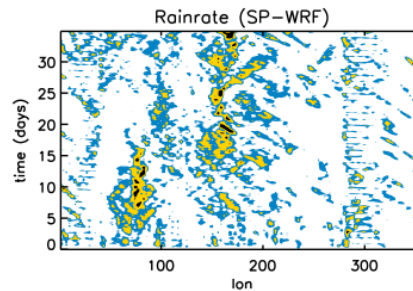


Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

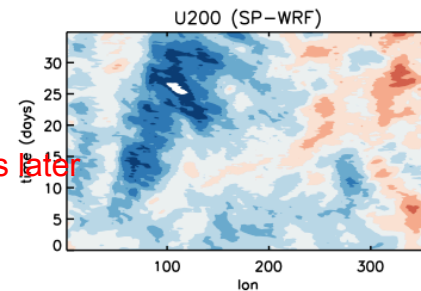
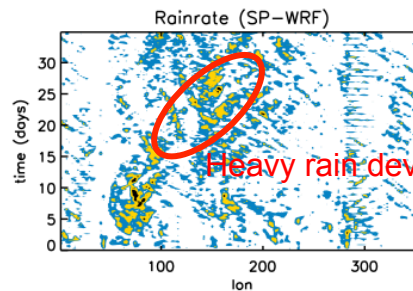
Obs.



2.8deg (32x4km)

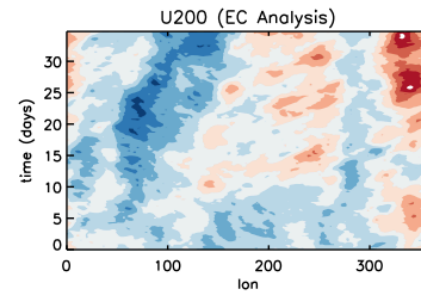
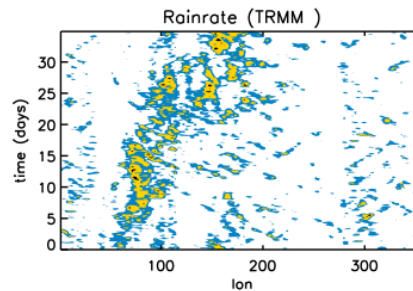


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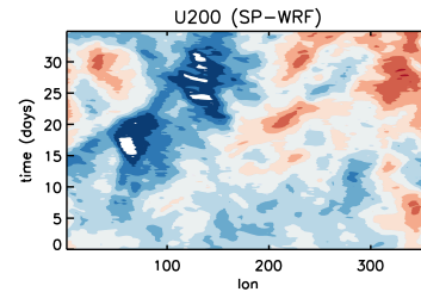
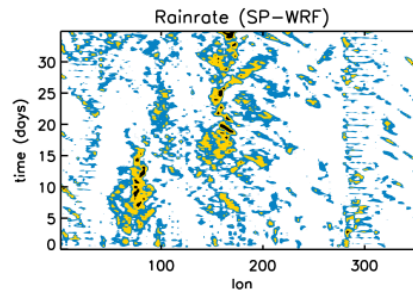


Nov 1 hindcast: SP-WRF (sensitivity to GCM resolution)

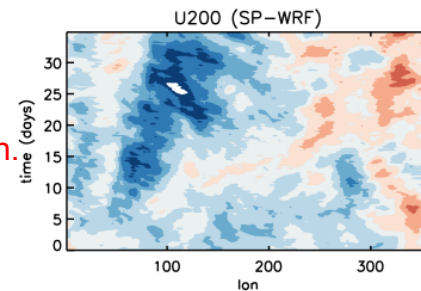
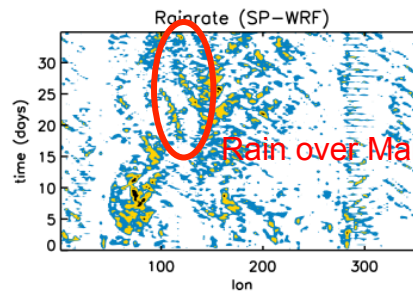
Obs.



2.8deg (32x4km)



0.7deg (12x4km)
8 x more exp.



Lessons learned so far

- MJO simulation in tradition hi-res. models depends crucially on the partitioning between grid-scale vs. parameterized convection; further “tuning” is needed; ultimately, parameterization should be doing most of the job (based on SP results)
- Past focus on convective closure assumptions as the key to simulating the MJO may be misguided; parameterization of vertical turbulent mixing is also clearly important (consistent with other large-domain CRM efforts, e.g., CASCADE, NICAM)
- The Maritime Continent barrier issue seems to be a serious problem in all models studied. High resolution appears to be a necessary but not sufficient condition for improvement